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Further Studies on the Preparation of Potato Granules by Solvent Methods

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DEHYDRATED COOKED MASHED POTATOES continue to be more widely used in households and institutions because of convenience in preparation. Their popularity and availability will be further increased as research and development improve their quality and find more economical and efficient methods for their production. Potato granules are enjoying a wide sale, a potato product in the form of shreds has been test-marketed in several cities, and a new form of dehydrated mashed potatoes known as potato flakes is in the development stage *(2, 3)*.

Studies on potato granules have sought to improve the add-back method and to determine the effects of different processing variables on granule quality *(1, 8, 9)*. These studies have emphasized that abrasion and impact must be minimized during drying. The powder that is produced must consist of discrete particles. These particles, although they may include some agglomerates of several cells each, are mainly individual cells. If these cells are broken during processing, the quality of the product is impaired due to the liberation of starch. Consideration has been given to replacing the pneumatic driers normally used by the industry with new types, such as the improved airlift and fluidized bed driers, which are designed to minimize damage to the potato cells.

Research has not only sought to reduce cell damage in the production of potato powder, but also to eliminate the add-back step and to avoid exposure of the potatoes to excessive heat. One method of attaining the latter objectives is that developed by a group at Kansas State College. This consists of freezing the mash, thawing, pressing out much of the juice, and then drying the partially dewatered potatoes. The most recent work on this method and on the properties of the product has been done by Hall *(5)*.

PREPARATION OF GRANULES BY SOLVENT METHODS

The preparation of granules by solvent methods also permits mild drying conditions to be used and the add-back step to be circumvented. One such procedure consists in removing most of the water from the mash by extraction with water-miscible organic liquids such as alcohol and dehydrating by a series of suspensions and filtrations. This method, which is described in a previous paper from this laboratory *(6)*, is simple, but has the disadvantage that about 7 to 10% of the total solids of the potatoes are extracted along with the water.

A second method used at this laboratory to dehydrate mashed potatoes with alcohol was based on a special type of distillation. Alcohol was added to the mash contained in a specially designed rotating evaporator *(4)* which was operated under such conditions that a relatively large amount of water distilled with the alcohol. Most of the water was removed by distillation, although a subsequent filtration was employed to remove the water and alcohol remaining in liquid form. Loss of potato solids was only 2 to 3% in the distillation method. However, dehydration by distillation was found to have certain drawbacks, particularly the long time required for water removal and the relatively high alcohol requirement.

As a further improvement in drying through the use of alcohol, dehydration of a mashed-potato suspension was effected by using optimum conditions under which water passes through a cellophane membrane at a substantially greater rate than alcohol. Passage of water through the wall of a collodion bag and subsequent evaporation of the liquid from the outer surface was first observed by Kober *(7)*, who called this phenomenon *pervaporation*. There are only a few references on the subject in the literature, and this technique seems to have been largely overlooked in dehydrating suspensions and solutions.

DEHYDRATION BY PERVAPORATION

Loss of potato solids is quite low when mashed potatoes are dehydrated by pervaporation. The alcohol requirement is also considerably lower than with either the suspension-filtration or distillation method. In pervaporation, the major part of the dehydration of a mashed-potato suspension in alcohol takes place by transmission of the water through the cellophane. Only a minor portion of the water is removed by a filtration step following the pervaporation.

When a solution of equal parts by weight of alcohol and water was placed in a cellophane bag, suspended in a forced-draft oven maintained at 60° C., the water content of the aqueous alcohol that passed through the membrane was about 70%. (The bags were formed from seamless regenerated cellulose sold specifically for dialysis; although wall thickness was not critical, 0.0016-inch membrane was ordinarily used). However, when a suspension of mashed potatoes in 1:1 alcohol-water was treated in the same manner, the water content of the pervaporated vapor was about 95%. Essentially the same result was obtained when the filtrate from mashed potato-alcohol-water mixture was pervaporated, indicating that the higher ratio of water: alcohol must be due to presence of the soluble potato solids.

Some consideration was given to the question of what types of solutes affect the ratio of water: alcohol passing through a cellophane membrane. Soluble solids in potatoes consist principally of sugars, citric and other organic acids, nitrogen compounds, and inorganic salts. The naturally occurring mixture of water-soluble potato solids is also soluble in 1:1 alcohol-water but only

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slightly soluble in alcohol. It is granted that solubilities of the individual substances in the complex mixture are undoubtedly influenced by the presence of the other substances. However, it was deemed worthwhile to investigate a few model systems in which pure substances of different solubilities in water and in alcohol were added, one at a time, to a 1:1 alcohol-water solution.

Addition of substances soluble in alcohol but only slightly soluble in water decidedly reduced the percentage of water in the transmitted vapor. However, addition of substances soluble in water but only slightly soluble in alcohol markedly increased the percentage of water in the pervaporated vapor. Addition of citric acid, soluble in both water and alcohol, resulted in pervaporated vapor of virtually the same composition as the control containing only alcohol and water.

Measurements taken periodically showed that the pervaporation rate of alcohol from a potato solids-alcohol-water mixture decreased with time and was finally reduced to an exceedingly low level. Alcohol passage was not detectable after 3 hours in an experiment at 42°-45° C. and after 22 hours at 25°-28° C. It is remarkable that by some mechanism the rate of transfer of alcohol through cellophane is diminished to this unmeasurably low level while water is being transmitted at a rapid rate. However, perhaps the most striking observation in this study is that temperature rise increases the pervaporation rate of water to a greater extent than the alcohol rate. In the laboratory preparation of granules, we have ordinarily employed 60° C. rather than a lower temperature in order to provide a high water transfer rate while transmission of alcohol is held to a low value.

TYPICAL LABORATORY PROCEDURE

An example of a laboratory procedure is as follows: Approximately 1000 g. of peeled potatoes (22% total solids) were sliced into ¾-inch pieces, steamed 35 minutes and mashed for 2 minutes at high speed in a planetary action mixer. Approximately 745 g. of absolute alcohol were added to the mashed potatoes and mixed to produce a slurry. The slurry was poured into a cellophane bag 1⅞ in. inflated diameter and suspended in a forced-draft oven maintained at 60° C. Pervaporation was continued until 60% of the water originally present had been removed. This required about 8 hours, the rate of pervaporation of water being approximately 0.15 g./sq. in./hr. The composition of the slurry before and after pervaporation is given in Table 1 (A). It can be seen that 472 g. of water diffused through the bag while only 20 g. of alcohol passed. The slurry was then fortified with 530 g. of absolute alcohol, which brought the liquid phase up to 80% alcohol. This is necessary to obtain a high percentage of single-cell particles in the final product. The effect of concentration of alcohol in contact with the potato solids on the yield of unicellular particles was discussed in our previous paper *(6)*.

The slurry was filtered with suction for 15 minutes, after which the filter cake weighed 400 g. [Table 1 (B)]. This filtration removed 261 g. of water, or 33% of that originally present. It will be noted that the ratio of alcohol: water was higher in the slurry than in the

TABLE 1

Dehydration of cooked mashed potatoes using pervaporation

Step	Weight in grams			
	Water	Alcohol	Potato Solids	Total
A. *Pervaporation*				
Original slurry	786	744	220	1750
Final slurry (after 8 hr.)	314	724	220	1258
Vapor	472	20	0	492
B. *Filtration*				
Slurry (alcohol added)	314	1254	220	1788
Filter cake	53	131	216	400
Filtrate	261	1123	4	1388
C. *Evaporation*				
Filter cake	53	131	216	400
Moist powder	41	0	216	257
Vapor	12	131	0	143
D. *Drying*				
Final product	16	0	216	232

filter cake. This was due to evaporation occurring during the vacuum filtration. The vapor was condensed and recovered by a dry ice trap and added to the filtrate to be included for materials balance purposes. The alcohol was then evaporated from the filter cake while it was reduced to a free-flowing moist powder by application of gentle agitation and mild heat [Table 1 (C)]. The temperature was not allowed to exceed 45° C. during evaporation of the alcohol. This was done to obtain a product virtually free of residual alcohol. Higher drying temperature results in retention of an appreciable amount of alcohol in the dry powder. The vapor from the evaporation step can also be condensed in a dry ice trap. The substantially unicellular powder obtained at the end of the evaporation step contained 16% moisture and is reducible to a lower value by tray drying or other means available. The powder, however, should not be exposed to temperatures exceeding 80° C. for more than ½ hour. In the example given [Table 1 (D)], the powder was dried one hour at 60° C. to reduce the granules to 6.8% moisture content.

In the typical experiment outlined in Table 1, 1527 g. of aqueous alcohol would have to be distilled to recover 1254 g. of absolute alcohol. This amount of absolute alcohol, plus makeup of 20 g. to replace the alcohol transmitted in pervaporation (the recovery of which was not attempted) was used in preparing 232 g. of final product. Expressed in another way 550 parts of alcohol, of which 541 are readily recoverable, are used to produce 100 parts of granules. In this materials balance, the small amount of alcohol lost in the azeotropic distillation to obtain absolute alcohol is neglected.

POSSIBILITIES ENVISIONED FOR PERVAPORATION IN THE FOOD INDUSTRY

Pervaporation of an aqueous alcoholic suspension of potato solids has not been attempted on a large scale. It is envisioned, however, that such a process could be developed, perhaps by pumping the slurry through a continuous section of cellophane tubing contained in a tunnel through which heated air is forced. In addition to its possible application in dehydrating mashed potatoes, this principle might also be used in other food work, such as in dehydrating aqueous alcoholic extracts of flavoring substances or in dehydrating plant tissue under mild conditions. In any event, these laboratory studies have shown that pervaporation can be used successfully to remove most of the water from mashed potatoes in the preparation of granules, and that granules so prepared have good color and unusual storage stability, and reconstitute to mashed potatoes of good flavor and texture.

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